arXiv:astro-ph/0010327 17 Oct 2000

Strong constraints on cosmology from galaxy clusters

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Abstract. In this work we show how galaxy clusters can be used to discriminate among different cosmological models. We have used available X-ray & optical cluster data to constrain the cosmological parameters as well as the cluster scaling relations, $T-M$ and L_x-T. We also show the power of future SZE data to constrain even more these parameters.

1 Constraints from optical & X-ray data

In several works, authors have used different cluster data sets in an attempt to constrain the cosmology. The usuall procedure is, starting from the Press-Schechter (PS) mass function, fit the experimental mass function or by using a given $T-M$ or L_x-M relation build some other cluster functions like the temperature, X-ray luminosity or flux functions, and then compare them with the corresponding data sets. This can be a dangerous process. First, when considering just one data set one ensures that its best fitting model is compatible with just that data set. Some care should be taken to check that the best fitting model is also consistent with other data sets. A second problem comes when the cluster scaling relations $T-M$ or L_x-M are assumed as fixed relations. However, the scatter in these relations are known to be important and they can introduce uncertainties in the final result. In order to avoid all these difficulties we made a fit to different data sets simultaneously without doing any assumption about neither the cosmology nor the $T-M$ and L_x-M relations. For the $T-M$ relation we assume the free-parameter relation:

$$T_{gas} = T_0 M_{15}^{\alpha}(1+z)^{\psi} \tag{1}$$

where T_0, α and ψ are our three free parameters. M_{15} is the cluster mass in $h^{-1}10^{15}M_{\odot}$ units. And similarly for the L_x-M :

$$L_x^{Bol} = L_0 M_{15}^{\beta}(1+z)^{\phi} \tag{2}$$

With these two scalings plus the PS formalism we were able to build the mass function, the temperature function and the X-ray luminosity and flux functions. As can be seen in Diego et al. (2000a) we found that only low density universes ($\Omega \approx 0.3$ with or without a cosmological constant) are compatible with recent determinations of these functions. In that work we also obtain some interesting limits for the parameters in the cluster scaling relations. Also important is to mention that by combining different data sets in our fit, we have reduced significantly the degeneracy in $\sigma_8 - \Omega$. In fact, we found a clear peak in the probability distribution at the position $\sigma_8 = 0.8, \Omega = 0.3$

2 Constraints from future SZE data

The possibilities of cluster data as a cosmological probe will increase when SZE surveys will be available. We are studing the possibilities of such data sets in order to know how well can we constrain the cosmological parameters and how these constraints depend on the assumptions made in, for instance, the $T-M$ relation (see Diego et al. 2000b). In Diego et al. (2000a) we showed that with present X-ray and optical cluster data it is not possible to break the existing degeneracy between low-density universes with or without Λ. In that work we found that both models were equally probable when describing the previous data. Will it be possible to break this degeneracy with future SZE data ? To answer this question we have compared two hypothetical future SZE surveys. The first one is based on the Planck satellite. This experiment will explore the whole sky at 9 mm frequencies (including those where the SZE is more relevant) and with resolutions up to 5 arcmin. We have estimated that with this experiment it will be possible to detect more than 30000 clusters through the SZE which will allow to build the curve $N(> S_{mm})$ (see Diego et al. 2000a). This curve can be used to fit the cosmological models. We have compared the $N(> S_{mm})$ curves corresponding to the two best fitting models ($\Lambda = 0$ and $\Lambda > 0$) found in Diego et al. (2000a). Both models predict very similar $N(> S_{mm})$ curves showing being therefore difficult to discriminate between the models. This is not surprising at all, since this curve is dominated by the cluster population at low redshift ($z < 0.7$) where the degeneracies among the models are more important. This point suggests the need of a different data set as a cosmological discriminator. Apart from the large number of detections, Planck will not provide, however, any estimate of the redshift of the clusters. In our second experiment we include the redshift of the clusters in order to account for evolutionary effects in the cluster population.

3 Evolution of the cluster population

One advantage of SZE surveys compared with X-ray and optical surveys is that the selection function is much less steep (with z) in the former case. Therefore, with the SZE, it seems that we should be able to observe deeper in redshift and consequently the information provided by a SZE survey would be, *a priori*, much more interesting in terms of evolution of the cluster population. Suppose we observe a region of the sky and find N SZE detections. Suppose now that we perform optical observations of these clusters and obtain their redshifts. Then we have S_{mm} and z for each one of the N clusters. With this kind of information, how large must be N in order to break the degeneracies found in table 1 of Diego et al. (2000a) ? We have tried to answer these questions by comparing the number of SZE detections above a given z for the two degenerated models requiring a difference in the models above 3σ level. In Fig. 1 we show our result. From this figure we conclude that with only a small subsample of ~ 300 clusters we could be able to break previous degeneracies. However, as we show in Diego et al. (2000b) the best results will come from combining the full sky $N(> S_{mm})$ given by Planck and the $N(> z)$ from a small sky patch selected from the SZE data.

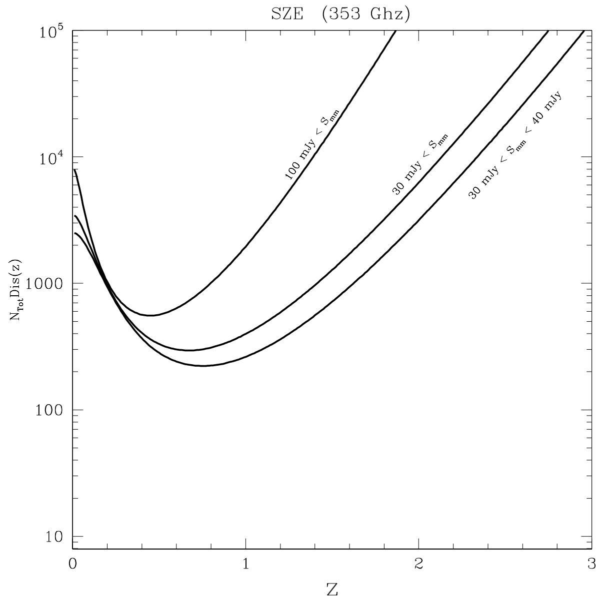

Fig. 1. Number of clusters with measured z required to distinguish (3σ) the two models in table 1 in Diego et al (2000a).

References

1. J.M. Diego, E. Martínez-González, J.L Sanz, L. Cayón, J. Silk. 2000a, submitted to MNRAS. astro-ph/0009042.
2. J.M. Diego, E. Martínez-González, J.L Sanz, J. Silk. 2000b, in preparation.